Antenna Rigging Angle Optimization Within Structural Member Size Design Optimization

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It is shown that the horizon rms deviation of the antenna from the best-fitting paraboloid is a representative measure of the cosine-weighted average rms for the complete elevation attitude range. Therefore, the horizon rms can be used as a substitute merit function in a structural redesign program that generates improved member size distributions to reduce the weighted-average rms. Validity of the substitution follows because: (1) the optimal rigging angle is a slowly changing function of changes in member size distributions; (2) the weighted average rms is not sensitive to small rigging angle changes; (3) at rigging angles near the optimal, ranking according to the minimum horizon rms is equivalent to ranking according to the minimum cosine-weighted average for alternative designs with different member size distributions.

I. Introduction

An appropriate choice of the antenna rigging angle, which is the elevation attitude of the antenna used in the field for setting the surface panels to the ideal paraboloid, provides a simple way to improve antenna gain by reducing the gravity contribution to the rms distortion of the surface. In accordance with convention, the distortion is considered with respect to the best-fitting paraboloid. The mathematical relationships entailed in rigging angle selection and illustrations of the effectiveness for the alternative objectives of either reducing the maximum rms distortion at the most unfavorable elevation attitude, or minimizing the average weighted rms distortion over the entire elevation range have been given previously (Ref. 1). For the first objective, it was found that the maximum rms distortion was minimized by choosing a rigging angle to make the rms at the horizon attitude equal to the rms at the zenith attitude. For the second objective, the weighting function was equal to the cosine of the elevation angle attitude. Cosine weighting minimizes the mathematical expectation of rms distortion when the antenna follows targets that are uniformly distributed within the observation space.

II. Incorporation of Rigging Angle Optimization Within Member Size Optimization Procedure

The present discussion describes additional numerical examples and parameter studies. The studies were performed to explore how the advantages of rms reduction via the choice of rigging angle can most simply be incorporated within a structural-optimization design procedure that seeks to reduce rms via the choice of member properties. The optimization design procedure currently being developed (Ref. 2) operates iteratively through successive stages by generating improved vectors of member property distributions that reduce the rms found for the size distribution vector that existed at the start of the stage. RMS for reduction in the present context is taken to be the average cosine-weighted rms for a 90-deg elevation attitude range. Since the structural deformations at every elevation attitude depend upon the changes in gravity loading and these depend upon the rigging angle, the following considerations are entailed in each stage:

(1) Computation of the starting rms requires the rigging angle of the structure with the current distribution of member properties. This implies a parameter study to determine the optimum rigging angle at the start of each stage.

(2) To generate the vectors of improved member properties, it is impractical to perform sequences of parameter studies to find the optimum rigging angles associated with all the alternative member size distributions. Therefore, it is preferable to have a single measure of performance that will serve as a valid guide in selecting the new sizes for each of the members.

The first consideration above does not entail a major computational difficulty, since the parameter study to determine the optimum rigging angle for a single structural design can be executed rapidly. Nevertheless, it would be useful to know whether or not there are significant changes in the rigging angle from the initial stage to subsequent redesign stages. Then if these changes are small, some computational advantage could be obtained by performing the parameter study only at the start of the procedure.

The simplest performance measure for the second consideration is the rms of some particular elevation attitude, e.g., the horizon (or nearest attitude to the horizon within the practical range), determined for the rigging angle that was optimal at the start of the stage. However, if this measure is to be used as an indicator of the weighted-average rms in judging the relative merits of alternative member property distributions, the following three assumptions are required to be true:

(1) *The optimal rigging angle is a slowly changing function of changes in member size distributions.* Therefore, the rigging angle at the end of each cycle (after a new distribution of member properties has been generated) will not differ significantly from the rigging angle at the beginning of the cycle.

(2) *The weighted-average rms distortion is not sensitive to small differences in rigging angle from the optimal.* Consequently, in conjunction with the first assumption, the weighted-average rms size computed for a new member property distribution will be reliable even though it is based upon the optimal rigging angle for the size distribution of the beginning of the cycle.

(3) *At the optimal or near optimal rigging angle, the ranking of alternative designs (different member-property distributions) according to the minimum horizon rms is the same as the ranking of these designs according to the minimum weighted-average rms.* Validity of this assumption permits the substitution of the horizon rms for the weighted-average rms as the merit function to be used in developing or evaluating improved member-property distributions.

The validity of the first assumption has been tested and confirmed by examining over 100 cases of alternative designs for the same antenna. The optimal rigging angle appears to be almost independent of the design. Furthermore, additional results tend to show that all antennas with the same focal length-to-diameter ratio (f/D) will have about the same optimal rigging angle with respect to an average, cosine-weighted rms. The angle is between

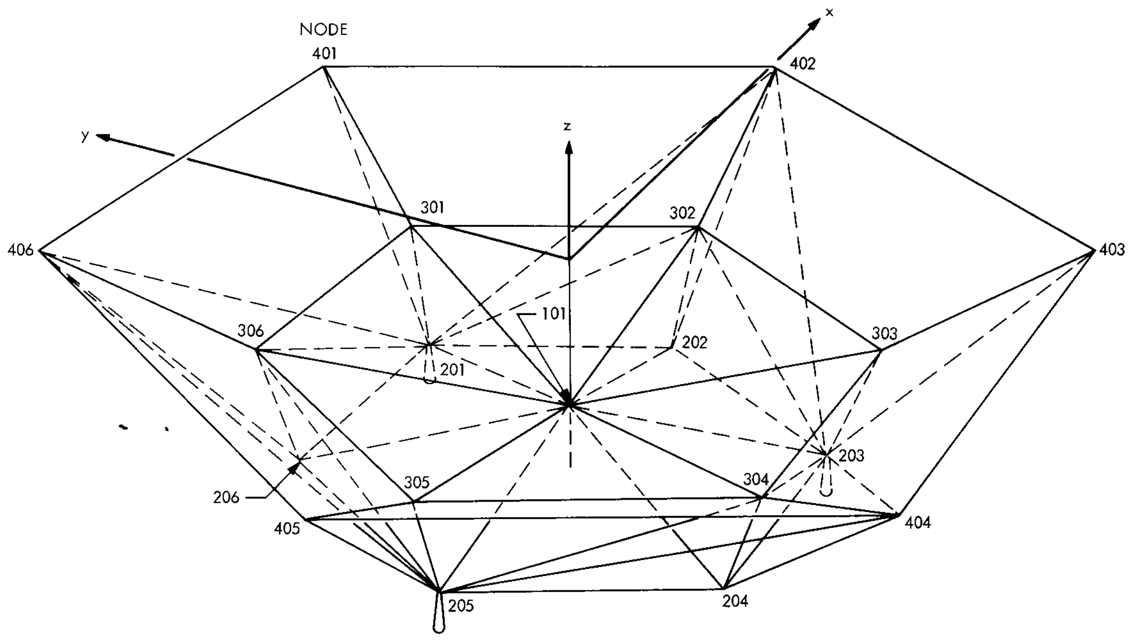

Fig. 1. Model of baseline structure

25 deg and 30 deg for an f/D ratio equal to 0.424. The examples and data that follow will present data to show that the second and third assumptions also are true.

III. Antenna Model

The hypothetical model reflector structure shown in Fig. 1 was used as the basis for the parameter studies. This is called the "baseline structure" and represents a simplified model of a practical reflector. It contains most of the essential features of typical reflector frameworks, notwithstanding that the surface and structure have been subdivided into a relatively coarse grid to expedite the computations. There are six identical ribs spaced at 60-deg increments, which are interconnected by the customary hoop and diagonal members. Three supports are shown at nodes 201, 203, and 205. The plane of the supports is taken to be capable of being rotated about the X-axis to vary the antenna elevation attitude. The Z-axis is the focal axis, and the Y–Z plane is a plane of symmetry. There are a total of 19 nodes, with three translational degrees of freedom permitted for each node. Therefore, excluding supports, there are 48 degrees of freedom in the model. Surface target nodes are 101, 301–306, 401–406, which provide 13 points for rms computation. There are six framing members of identical topology and similar structural function in each of ten different groups (five-rib member, three-hoop member, two-diagonal member), resulting in a total of 60 members.

IV. Rigging Angle Studies

The initial rms analysis was made for a basic model in which all the framing members were assigned identical cross-sectional area properties. Subsequently, additional designs were generated by means of new property distributions in which the areas common to all six members within each of the ten groups were changed relative to the areas for the remaining nine groups.

Studies to find the optimal rigging angle with respect to the minimum cosine-weighted average rms were performed for each of 21 designs. These consisted of a basic design and 20 additional designs in which the member areas for each of the ten groups were relatively one-half and twice the areas for the remaining nine groups. The results were plotted to show the weighted average rms as a function of the rigging angle for each structure of the 21 cases. It was found that several curves for individual cases were quite similar so that only five distinct curves, which are shown in Fig. 2, were sufficient to represent all of these cases, each curve representing possibly more than one case.

Figure 3 shows the results of the rigging angle parameter studies that were based upon the analytical models of the 210-ft antenna and three additional 85-ft antenna models. These are considerably more complex in that

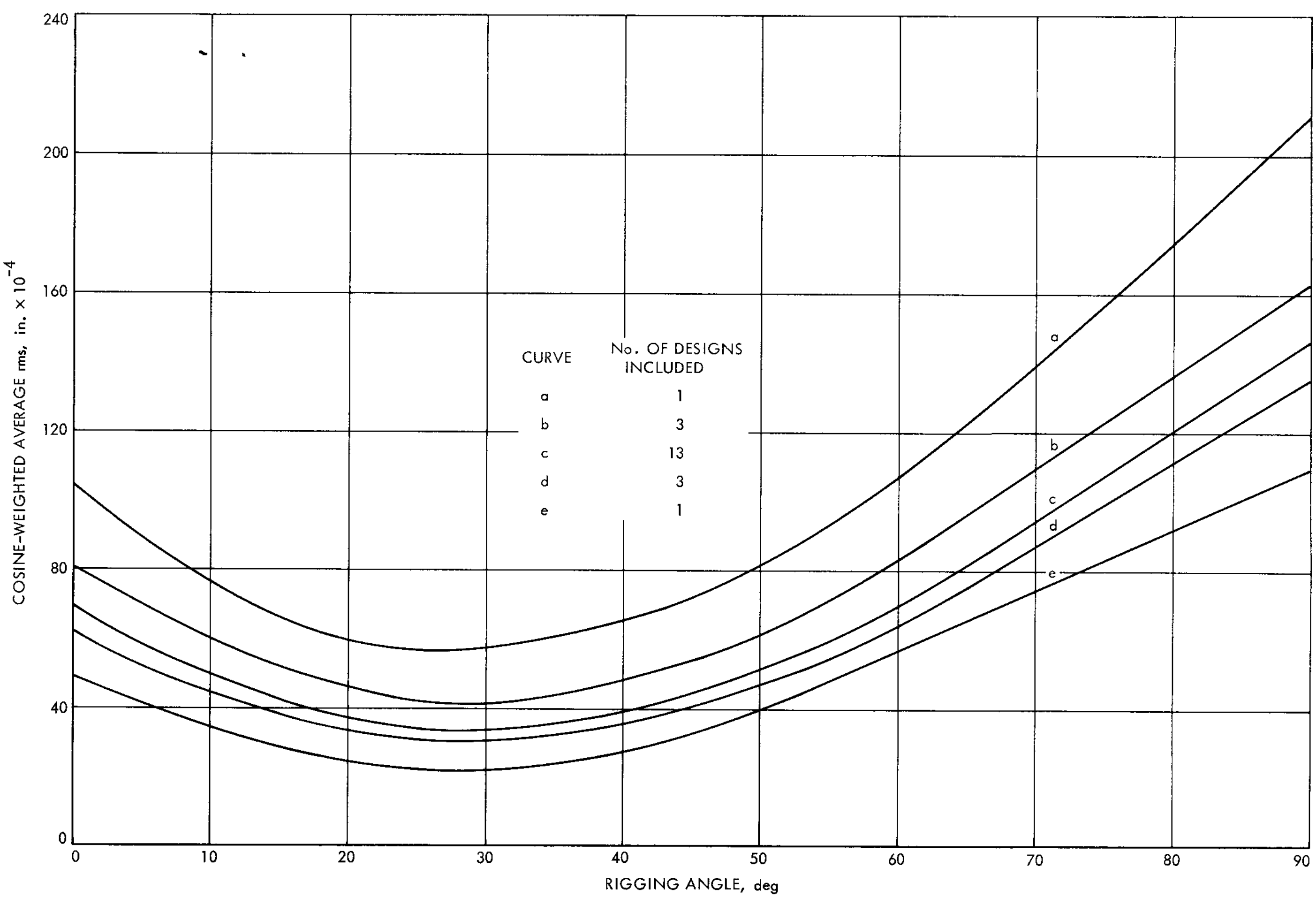

Fig. 2. Weighted average rms versus rigging angle, baseline structure

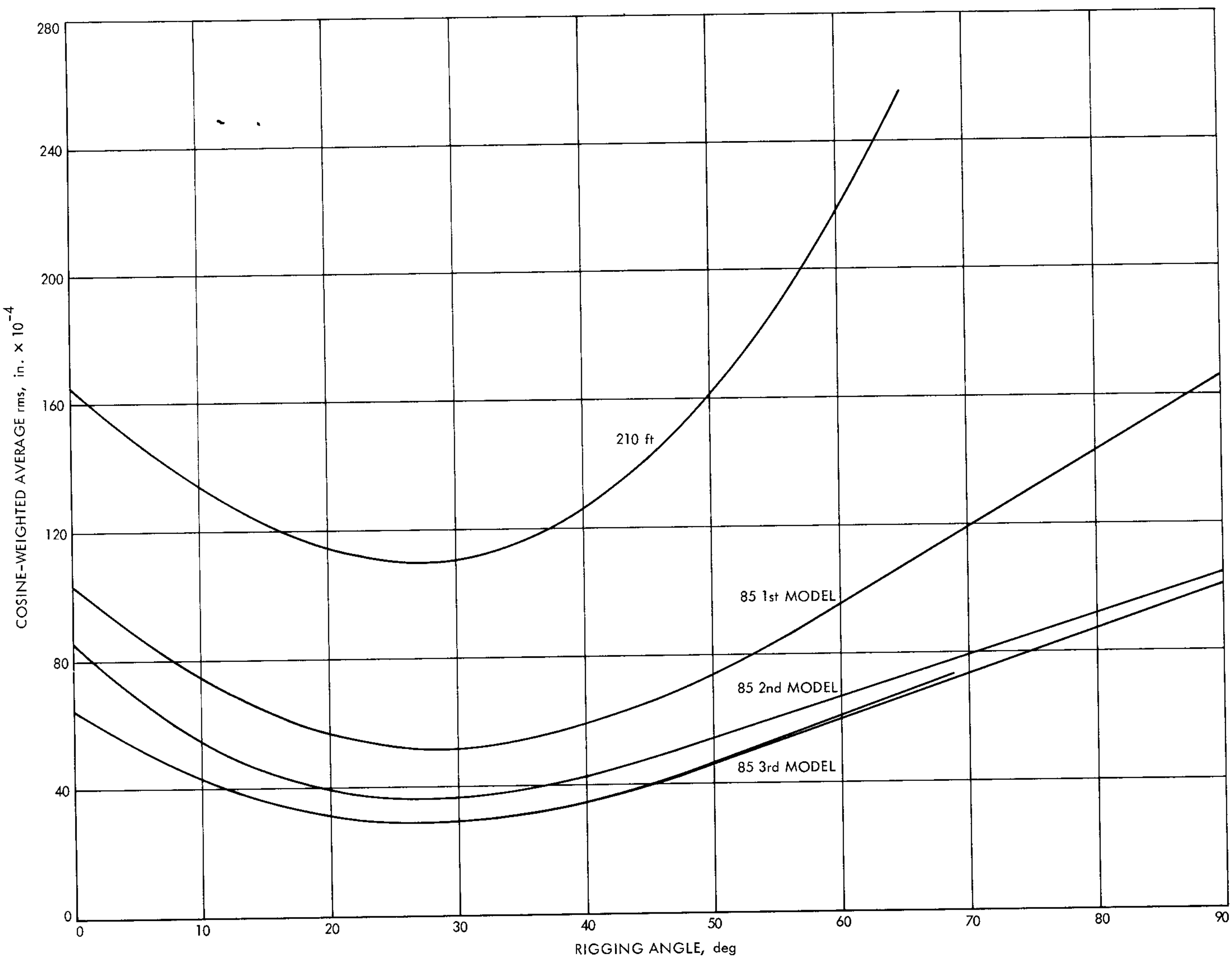

Fig. 3. Weighted average rms versus rigging angle, 210- and 85-ft antennas

much finer subdivisions were used in defining the structural grids for the framework idealization, each framework consisting of more than 1000 members and degrees of freedom, and over 100 surface target nodes. In all cases, it can be seen that the optimal rigging angle is always close to 30 deg and that the weighted average does not vary by more than a few percent for rigging angles between 25 and 35 deg. Therefore, these figures confirm the validity of the first two assumptions.

In Fig. 4 the cosine-weighted rms for the antenna rigged at 30 deg is plotted as a function of the elevation attitude for the 21 structural variations of the baseline structure. As in Fig. 2, similarity of some of the curves permitted grouping so that all cases could be represented by a relatively smaller number of curves. The figure shows that none of the curves cross each other. Therefore, it can be concluded that in comparing any two curves the one that has a relatively lower 0-deg (horizon attitude) rms value also has a relatively lower weighted rms value at all elevation attitudes, resulting in a relatively smaller area under the entire curve. Since the area under the curve is a measure of the weighted-average rms value, it follows that the horizon rms is also a measure of the weighted average. Therefore, this confirms the third assumption.

V. Conclusion

It has been shown that with the optimal rigging angle, the horizon rms deviation of the antenna from the best-fitting paraboloid is a representative measure of the cosine-weighted average rms for the complete elevation attitude range. Therefore, the horizon rms can be used as a simplified substitute merit function in a structural redesign program that generates improved member size distributions to reduce the weighted-average rms. Validity of the substitution follows because: (1) the optimal rigging angle is a slowly changing function of changes in member size distributions; (2) the weighted-average rms is not sensitive to small rigging angle changes; and (3) at rigging angles near the optimal, ranking according to the minimum horizon rms is equivalent to ranking according to the minimum cosine-weighted average for alternative designs with different member size distributions.

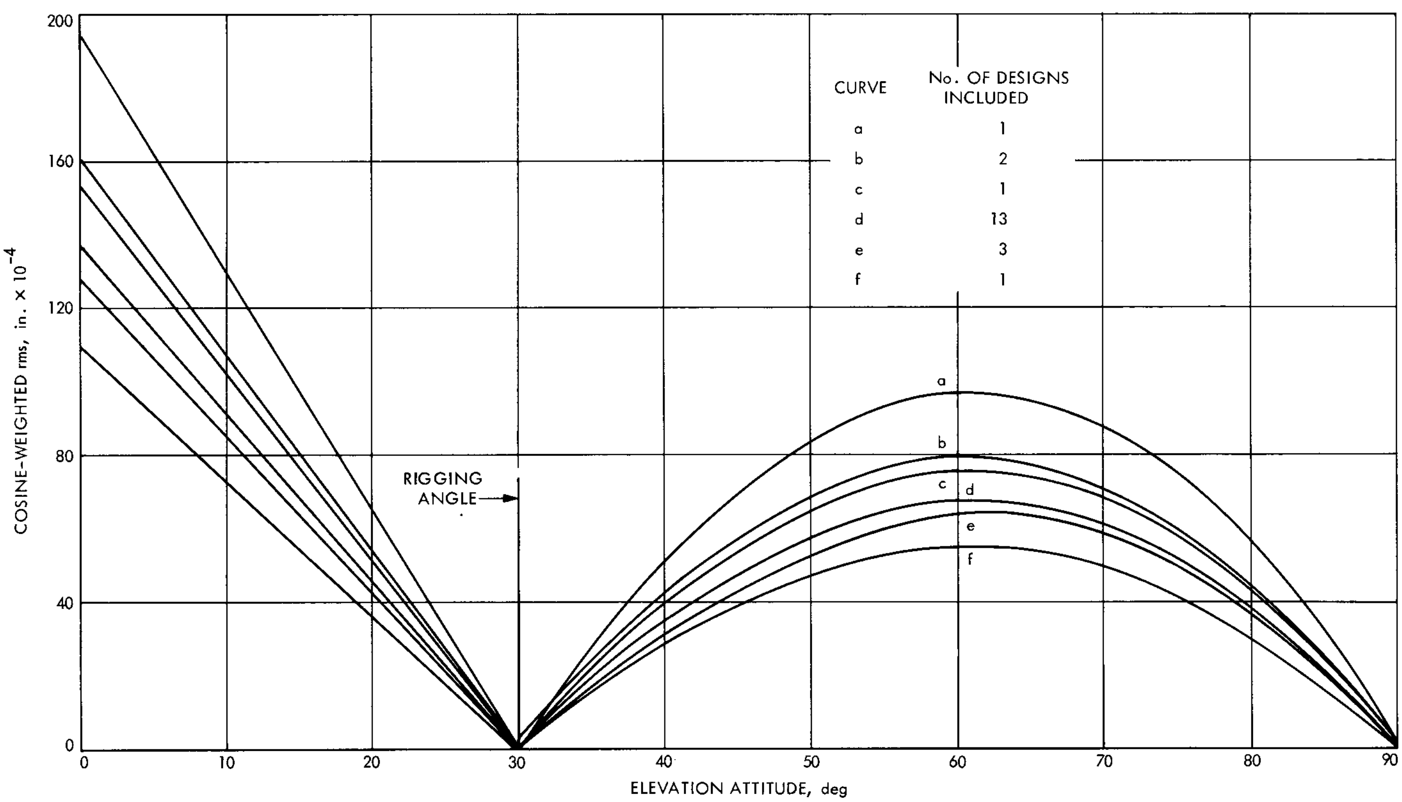

Fig. 4. Weighted rms versus elevation attitude, baseline structure

References

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2. *Antenna Reflector Design Optimization,* Philco-Ford Corp., WDL Div., March 1970.